

330173
P. 44

**SEGMENT SPECIFICATION
FOR THE
PAYLOAD SEGMENT
OF THE
REUSABLE REENTRY SATELLITE

RODENT MODULE VERSION**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Contract NAS9-18202
DRL 04**

**Prepared by
Science Applications
International Corporation**

**Prepared for
Lyndon B. Johnson
Space Center**

SAIC RRS-040



An Employee-Owned Company

**21151 Western Avenue
Torrance, California 90501**

RRS-RM-200
330173
P. 44
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Contract NAS9-18202
DRL 04
SAIC RRS-040
Science Applications International Corporation
21151 Western Avenue
Torrance, California 90501

**SEGMENT SPECIFICATION
FOR THE
PAYLOAD SEGMENT
OF THE
REUSABLE REENTRY SATELLITE

RODENT MODULE VERSION**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Contract NAS9-18202
DRL 04**

**Prepared by
Science Applications
International Corporation**

**Prepared for
Lyndon B. Johnson
Space Center**

SAIC RRS-040



An Employee-Owned Company

**21151 Western Avenue
Torrance, California 90501**

CONTENTS

Section	Page
1 SCOPE	1
2 APPLICABLE DOCUMENTS	1
3 REQUIREMENTS	1
3.1 SYSTEM DEFINITION	1
3.1.1 Payload Segment (PS)	2
3.1.2 Mission	5
3.1.3 Threat	5
3.1.4 Interface Definition	5
3.1.5 Major Component List	8
3.1.6 Government Furnished Property (GFP) List ..	8
3.1.7 Government Loaned Property List	8
3.1.8 Operational and Organizational Concepts ..	9
3.1.9 Specification Tree	9
3.2 CHARACTERISTICS	9
3.2.1 Segment Characteristics	9
3.2.2 Subsystem Characteristics	29
3.2.3 Reliability	29
3.2.4 Maintainability	29
3.2.5 Environmental Conditions	29
3.2.6 Transportability	29
3.2.7 Reusability	29
3.3 DESIGN AND CONSTRUCTION	29
3.3.1 Cage Coatings	29
3.3.2 Cage Materials	29
3.3.3 Cleanliness	29
3.3.4 Mechanical Design Criteria	30
3.3.5 Off-Loading	31
3.3.6 Purging	31
3.3.7 Handling and Lifting	31
3.3.8 Computer Resources	31
3.3.9 External Power	31
3.3.10 Alignment Reference	32
3.3.11 Interface Connector Verification	32
3.4 DOCUMENTATION	32
3.5 LOGISTICS	32
3.5.1 Maintenance	32
3.5.2 Supply	32
3.5.3 Facilities and Facility Equipment	33
3.5.4 Recovery Force	33
3.6 PERSONNEL AND TRAINING	33
3.6.1 Personnel	33
3.7 PRECEDENCE	34

CONTENTS (Cont.)

Section		Page
4	QUALITY ASSURANCE PROVISIONS	34
5	PREPARATIONS FOR DELIVERY	34
6	NOTES	34
Appendix I: Ground/Peculiar Support Equipment (GSE/PSE for the Reusable Reentry Satellite (RRS) Rodent Module (RM)		
Appendix II: Grount Test Module for the Reusable Reentry Satellite (RRS) Rodent Module (RM)		

Figure		Page
1	RRS Functional Diagram	1
2	RRS Payload Module	2
3	RRS Rodent Module	4
4	Experiment Module Interfaces	6
5	Support Module Interfaces	7

TABLES

Table		Page
I	Time Tag Format	16
II	Trace Contaminants Limits and Rates	24

1. SCOPE

This specification establishes the performance, design, development, and test requirements for the Reusable Reentry Satellite (RRS) Rodent Module (RM).

2. APPLICABLE DOCUMENTS

As specified in RRS-SS-100, paragraph 2.0.

3. REQUIREMENTS

3.1 SYSTEM DEFINITION

The RRS System is composed of the Payload Segment (PS), Vehicle Segment (VS), and Mission Support (MS) Segments. The RRS functional block diagram, shown in Figure 1, is described in RRS-SS-100.

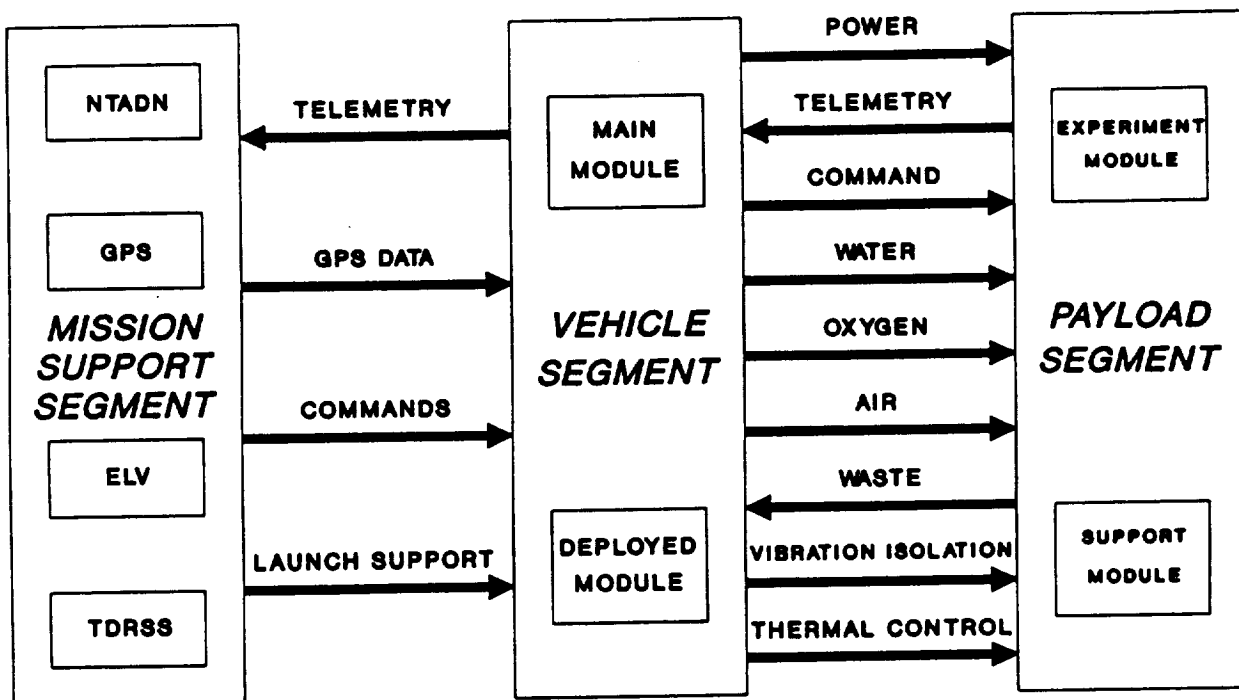


Figure 1. RRS Functional Diagram

3.1.1 Payload Segment (PS). The PS is composed of multiple Payload Module (PM) configurations, each serving distinct experimental objectives and each having its own distinct version of the Payload Segment Specification. The PM, shown in Figure 2, may have any internal configuration consistent with the interface requirements specified in RRS-IFS-101. The primary configuration, which is used by the Rodent Module, consists of a Support Module (SM) and an Experiment Module (EM) which fits in the upper portion of the SM. The SM consists of a pressure vessel with the payload support equipment installed in the lower portion. For the purposes of this specification, Payload Module (PM) and Rodent Module (RM) will be used interchangeably.

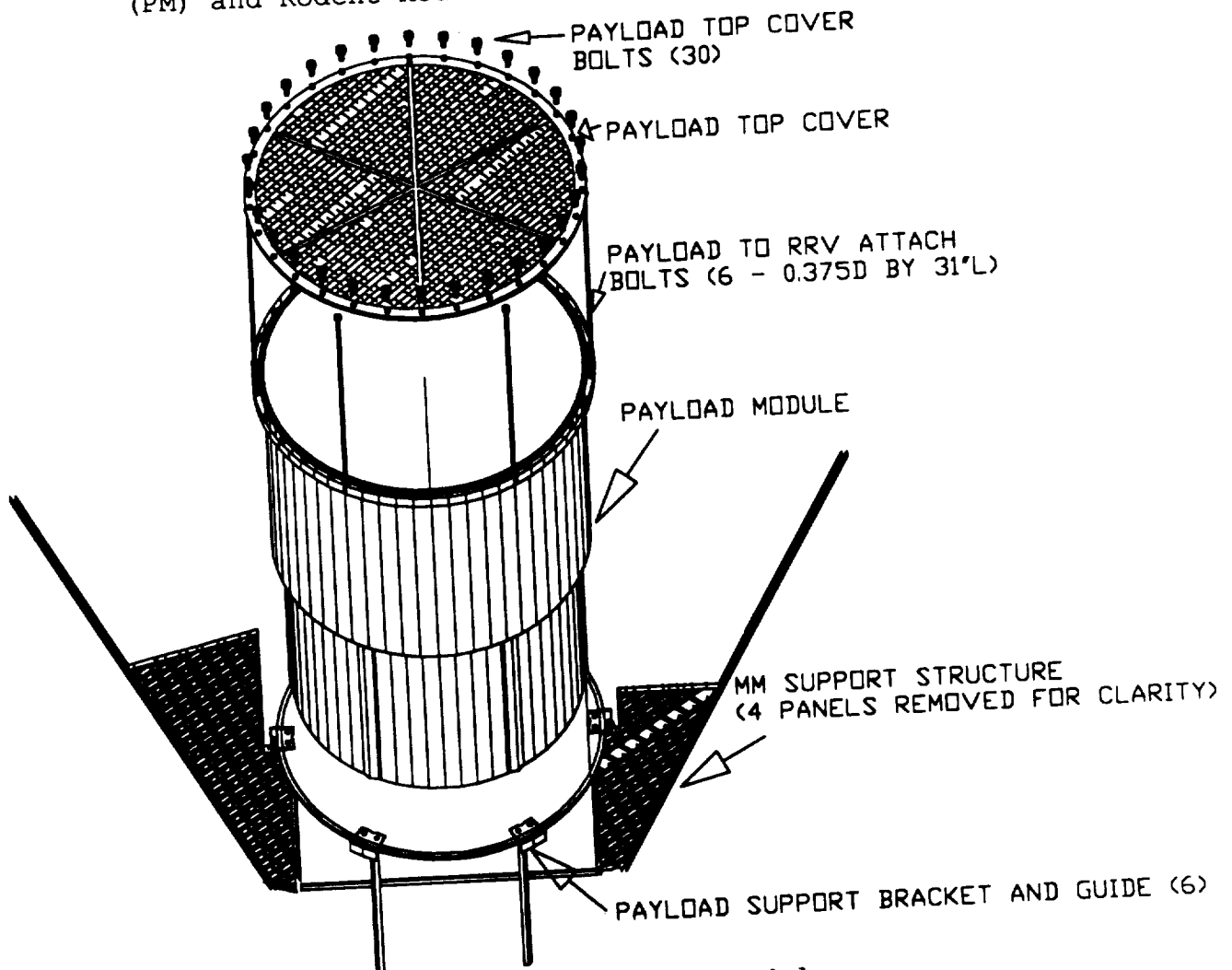


Figure 2. RRS Payload Module

3.1.1.2 Ground Test Module (GTM). The GTM is a nonflight version of the generic PM, and is used to generate experiment control data. The GTM outputs ground test data to the Vehicle Emulator (VE) and accepts commands from the VE to run ground experiments.

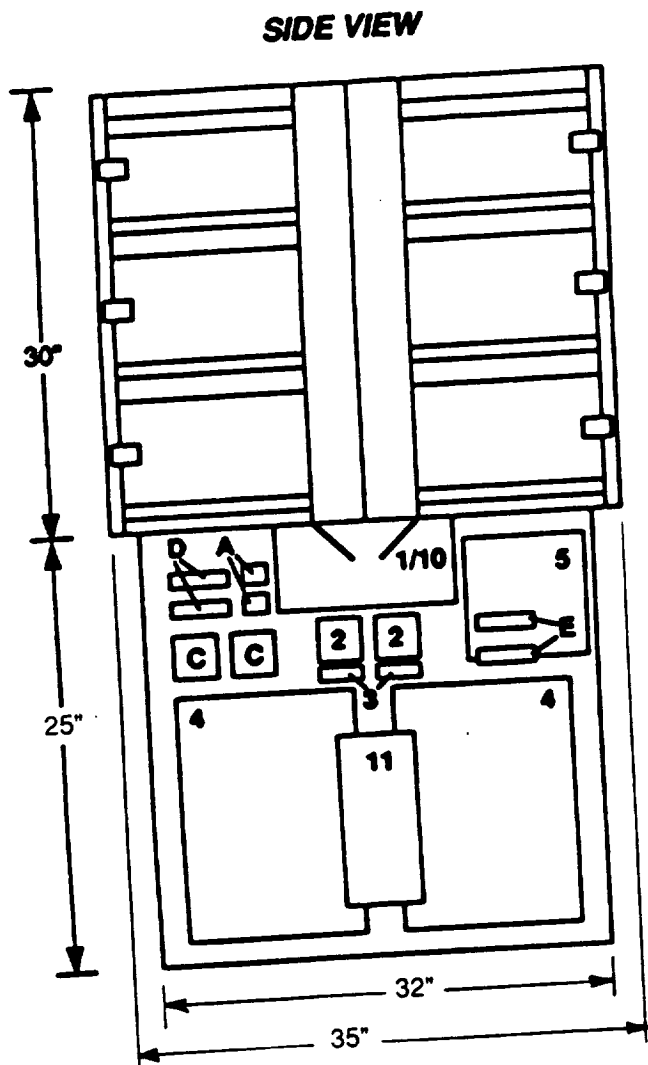
3.1.1.3 Payload Module Emulator (PME). The PME emulates the PM/GTM electrical and mechanical properties and interfaces to permit full validation of the RRV/PM interface using the Reusable Reentry Vehicle (RRV) and/or VE.

3.1.1.1 Rodent Module. The RM, as shown in Figure 3, shall be designed as a self-contained unit which provides a habitable environment to support rodents by using utility resources of the RRS vehicle. As a minimum, the RM will include rodent habitat cages; food; water control; solid waste storage; contamination control; control of the atmosphere temperature, composition, and relative humidity; mechanical, thermal, and electrical connections with the vehicle; data collection and storage; and experiment control. The RM is intended to be used to support several species of rodents including rats, mice, and hamsters.

a) The initial version of this specification will only contain requirements for rats; however, the design of the RM for rats shall not preclude the modifications needed to allow support of smaller rodents such as mice and hamsters.

b) The RM is composed of two elements, an Experiment Module (EM) and a Support Module (SM).

3.1.1.1.1 Experiment Module. For the RM configuration, the EM houses and supports living payloads and contains the cages, lighting, food, water control, atmosphere, instrumentation, solid waste control, ventilation, and imaging. Environmental conditions imposed on the EM will be a result of the RRV/ PM environmental impositions as



- 1/10 = Debris Trap/Waste Filter
- 2 = Fan
- 3 = Check Valve
- 4 = CO₂ Absorber
- 5 = Heat Exchanger
- 9 = Fans
- 11 = Pressure Relief Valves
- 12 = Air Flow Control Valve

- A = CCD Camera
- B = Hard Disk
- C = Cassette Tape
- D = PM Processor
- E = Power Converters

SM LAYOUT (TOP VIEW)

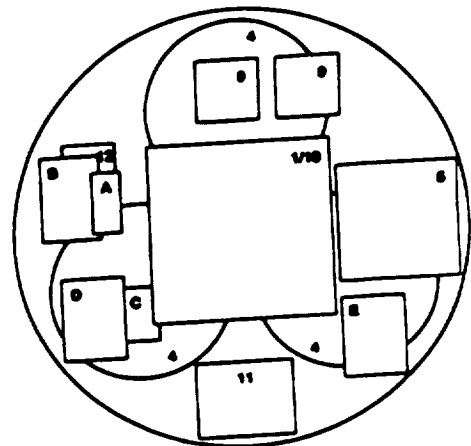


Figure 3. RRS Rodent Module

well as the RRV/PM and EM/PM attenuation capabilities. The EM functional block diagram is shown in Figure 4.

3.1.1.1.2 Support Module. The SM consists of the pressure vessel, Environmental Control/ Life Support System (ECLSS), image storage system, lighting harness, instrumentation assembly, solid waste container, and supporting structure, as well as the requisite interconnectors, wiring harness, external interface connectors, tubing runs, and attach fittings. The SM functional block diagram is shown in Figure 5.

3.1.2 Mission. As specified in RRS-SS-100, para 3.1.2.

3.1.3 Threat. As specified in RRS-SS-100, para 3.1.3.

3.1.4 Interface Definition

3.1.4.1 RRV/RM

- a) This interface is defined in Specification RRS-IFS-101. All elements within each segment shall conform to this interface specification.
- b) Except for variations resulting from ground versus flight module versions, the physical interfaces for all PMs shall be identical.
- c) A minimum of 49 lbs of oxygen shall be stored by the RRV.
- d) A minimum of 20 lbs of air shall be stored by the RRV.
- e) A maximum of 133 lbs of consumable water shall be stored by the RRV.
- f) The RM shall receive from, and respond to, commands received from the RRV.
- g) When commanded, the RM will transfer experiment data to the RRV via digital serial bit stream compatible with MIL-STD-1553.

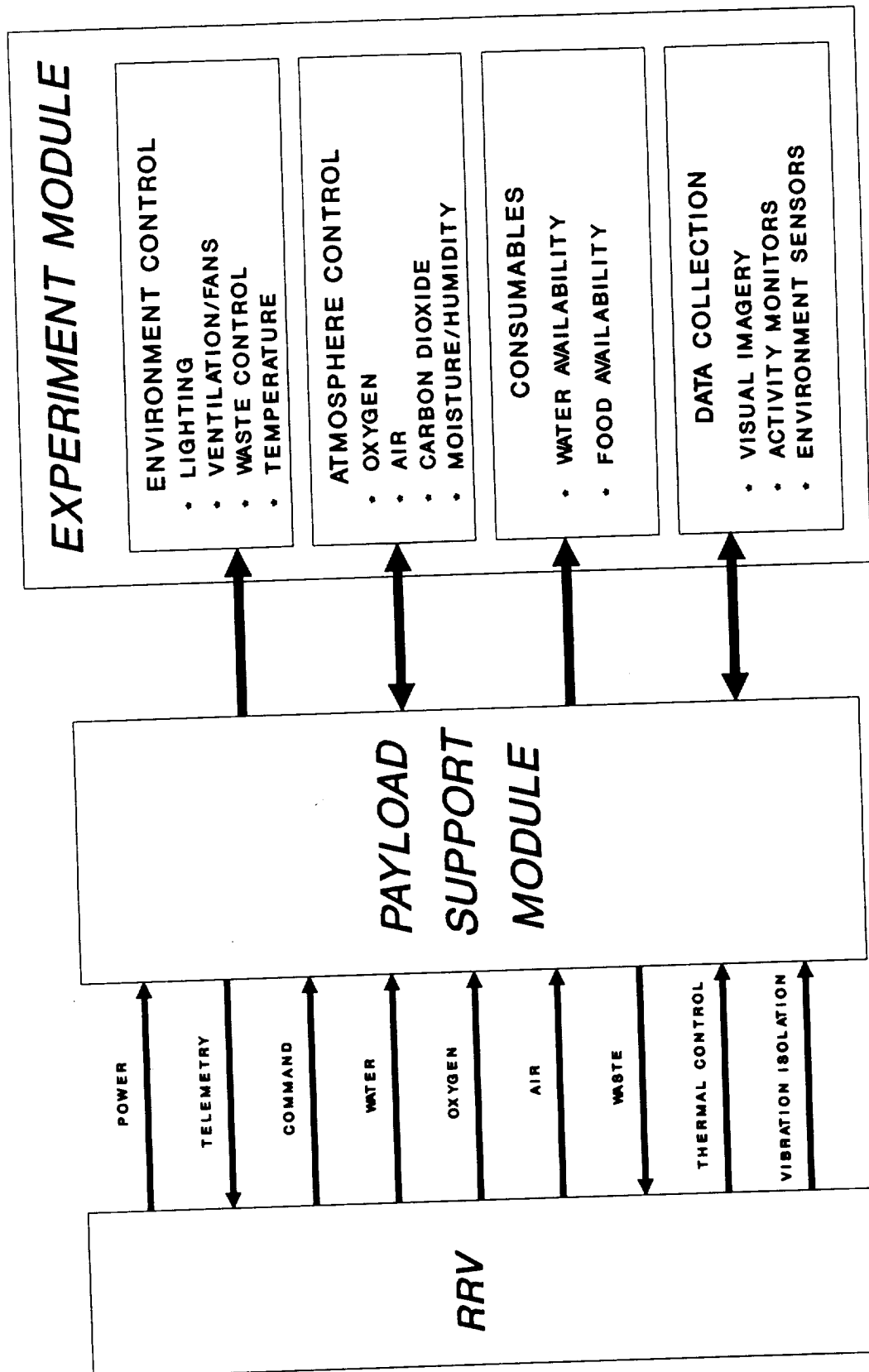


Figure 4. Experiment Module Interfaces

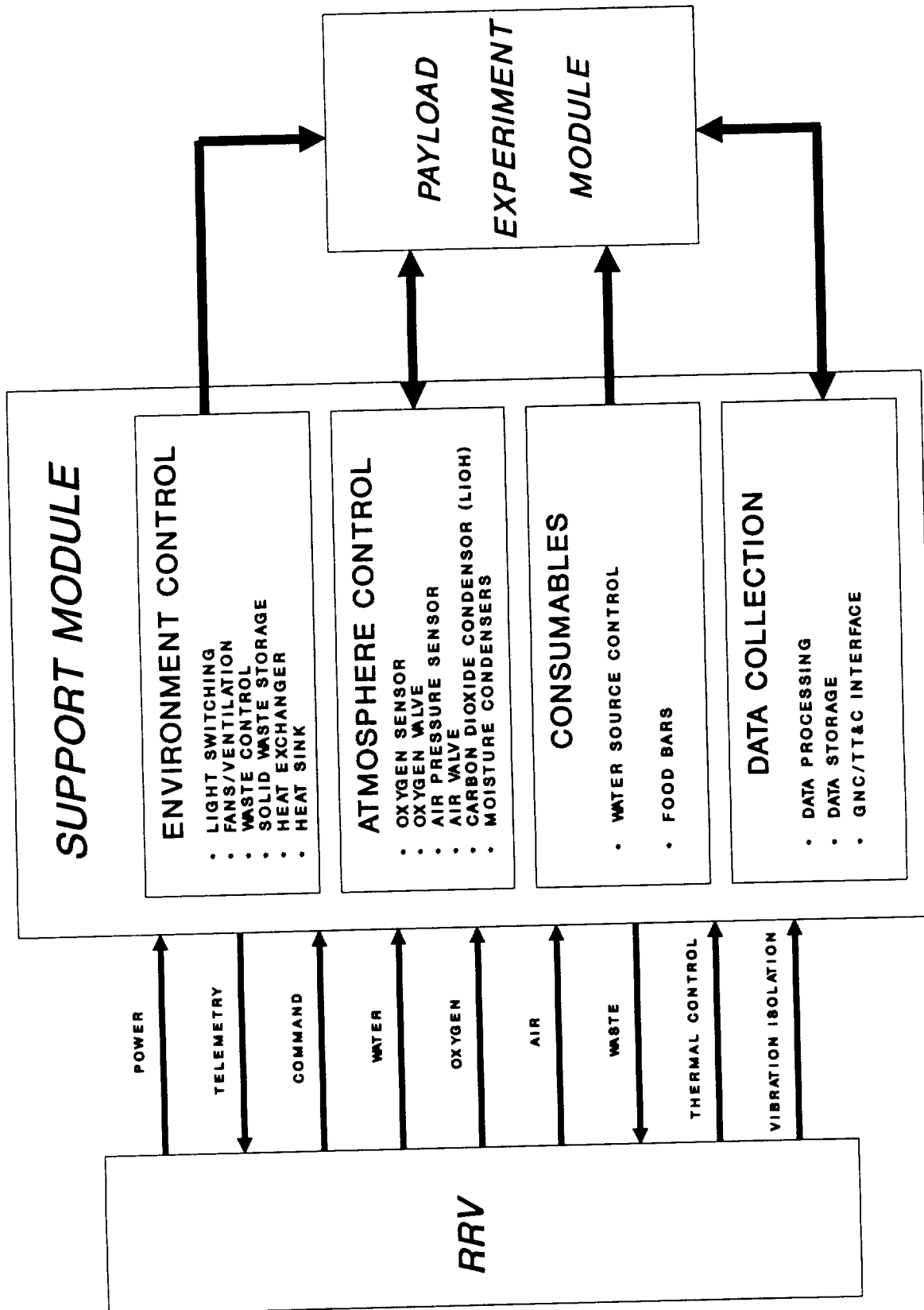


Figure 5. Support Module Interfaces

3.1.4.2 EM/SM. This interface is defined in Specification RRS-IFS-201. This interface is internal to the PM, and is designed with quick disconnects to the extent possible for flexibility in meeting accessibility timelines.

3.1.5 Major Component List

- a) Cages (up to 18)
 - 1) Access door.
 - 2) Lixits (2).
 - 3) Illumination (2 light sources - incandescent or halogen).
 - 4) Food bars.
 - 5) Attach fittings - cage to RM structure (cage readily removable).
 - 6) Video camera lenses/transducers (2)
- b) Support structure.
- c) Wiring harness.
 - 1) Instrumentation.
 - 2) Power distribution.
 - 3) Lighting.
 - 4) Video imaging.
- d) Tubing runs.
 - 1) Water distribution (lixits).
 - 2) Quick disconnects.
- e) Ducting, baffles for ventilation, atmosphere control
- f) ECLSS hardware.

3.1.6 Government Furnished Property (GFP) List. GFP will include all expendables for the experiment such as food, water, experimental animals, and any mission-peculiar system elements.

3.1.7 Government Loaned Property List. As specified in RRS-SS-100, paragraph 3.1.7.

3.1.8 Operational and Organizational Concepts. As specified in RRS-SS-100, paragraph 3.1.8.

3.1.9 Specification Tree. The RRS System specification tree is defined in RRS-SS-100, paragraph 3.1.9.

3.2 **CHARACTERISTICS**

3.2.1 Segment Characteristics

3.2.1.1 Experimental Specimens Installation. Final installation of the experimental specimens and support equipment into the PM shall be performed on the launch pad.

3.2.1.2 GTM Checkout Utilization. The GTM element shall generate experiment data to be provided to the VE.

3.2.1.3 PM Installation Prior to Launch. The PM shall be installed into the RRV before the RRV is mated with the launch vehicle. Some of the experimental specimens and support equipment may also be installed into the PM before mating has occurred.

3.2.1.4 PME Checkout Utilization. The PME shall simulate PM/GTM operations during RRV and/or VE checkout.

3.2.1.5 SM Weight. The maximum SM weight shall not exceed 370 lbs.

3.2.2 Subsystem Characteristics

a) Experiment Module

- 1) Animal health and well-being shall be the primary consideration in the design, construction, and operation of the RM and ground test modules - no aspect of the module design or operation shall degrade experiment objectives.

- 2) The module shall be capable of supporting rodents in all stages of their post-juvenile life cycle.
- b) Support Module: The SM shall provide the required environmental control and life support to the EM test subjects.

3.2.2.1 Experiment Module

3.2.2.1.1 Control

- a) RM control shall primarily be performed by pre-programmed, on-board control logic.
- b) The capability for remote control functions exercised from the NTADN shall exist.
- c) The approach shall be to exercise "management by exception"; that is, to program operations pre-flight and allow on-board logic to establish such test conditions as the level of artificial g's and the light/dark schedule.
- d) On-board logic shall notify the ground control whenever designated parameters (temperature, pressure, g's, etc.) are tending toward pre-established allowable limits.
- e) Ground controllers shall have the ability to intervene and adjust affected parameters as necessary to remain within limits.

3.2.2.1.1.1 Pre-Programmed Commands. Pre-programmed commands shall be loaded into on-board computer memory to exercise the designated system functions to carry out the experiment program.

3.2.2.1.1.2 Real-Time Commands

- a) Real-time commands shall be limited to emergency situations, as all experiment procedures will be pre-planned and accomplished by on-board mission function sequencers.
- b) The capability for direct intervention using Tracking and Data Relay Satellite System (TDRSS) S-band or equivalent channels shall be incorporated to provide

mission controllers with the ability to override the automatic sequencer.

3.2.2.1.2 Data

- a) All data recorded or transmitted by the RM shall be time-tagged to allow unique and unambiguous reconstruction of the history of the mission.
- b) All data from each mission shall include mission identification words or bits which are unique to the module and mission.

3.2.2.1.2.1 Ground Test Data. The Ground Controlled Experiment Model (GCEM) shall collect the same data as the RM. Ground test data may be transferred by hard line for immediate display and recording with Ground Support Equipment (GSE).

3.2.2.1.2.2 Orbital Flight Data

3.2.2.1.2.2.1 Environment

- a) The RM shall record module status, module environment, experiment housekeeping, and experiment status parameters and measurements at regular intervals during a flight.
- b) Snapshots of the records shall be telemetered during flight to allow monitoring of the progress of the flight and management of ground control experiments.

3.2.2.1.2.2.2 Experiment. The EM shall collect experiment parameter data, as directed by the user. This information shall include, but not be limited to:

a) Photo Imagery.

- 1) The EM shall collect photo images of the inside of each cage at scheduled times during each flight.
- 2) Image resolution shall be 256 x 256 x 4 pixels with the capability for 512 x 512 x 8 pixels resolution if needed on a limited basis.

- 3) The minimum number of images collected shall be once per cage per hour.
- b) Activity Sensor.
 - 1) The EM shall monitor activity within each cage.
 - 2) The Activity Sensor shall monitor activity, in 7-second increments, for a period not to exceed 17 minutes. At that time, the number of activities sensed will be transferred to memory, and the activity counter reinitiated.

3.2.2.1.2.3 Post-Flight Data

3.2.2.1.2.3.1 Environmental Data. The EM shall collect environment measurements for analysis after recovery.

3.2.2.1.2.3.2 Experiment Data. The EM shall provide to the SM a complete record of experiment data.

3.2.2.2 Support Module

3.2.2.2.1 Control. As specified in 3.2.2.1.1

3.2.2.2.1.1 Pre-Programmed Commands. As specified in 3.2.2.2.1.1.

3.2.2.2.1.2 Real-Time Commands. As specified in 3.2.2.1.1.2.

3.2.2.2.1.3 Ground Test Commands

- a) A duplicate set of commands to those sent to the flight PM shall be provided to the GTM via the VE.
- b) This command set shall differ only in those flight-specific commands not applicable for the GCEM.

3.2.2.2.2 Data. System data includes spacecraft (housekeeping) data and experiment data.

- a) Key RRS events shall be received by the RM, time-tagged, and stored with other experiment data.
- b) The SM shall accept control data from the RRV for further processing.

3.2.2.2.2.1 Ground Test Data

- a) A complete record of ground test data shall be maintained for establishment of GCEM operating conditions.
- b) The data specified in the TBD telemetry and instrumentation list for the RM, with the exception of flight-specific information, shall be acquired and provided to the PI.

3.2.2.2.2.2 Orbital Flight Data

- a) Experiment data is primarily recorded on-board for downloading and recovery post-flight.
- b) The SM shall provide the capability for in-mission downlinking of all experiment data collected within the previous 24 hours when directed, within the constraints of Telemetry, Tracking, and Control downlink sizing.
- c) Spacecraft data pertinent to experiment operations shall be telemetered during flight in order to monitor experiment progress and to verify experimental conditions, as well as to enable the GCEM to duplicate the orbital system's conditions and time history of temperature, pressure, etc.

3.2.2.2.2.2.1 Environment - RM

- a) Data on the RM experiment environment specified by the Principal Investigator (PI) as essential to in-flight and/or post-flight operations shall be detected and recorded for immediate or intermittent telemetered downloading or post-flight recovery.
- b) The environmental data specified in the telemetry and instrumentation list shall be recorded for retrieval after recovery.
- c) The RM shall receive RRS event timing signals for inclusion in the RM data.

3.2.2.2.2.2.2 Flight Images

- a) Video imaging shall be provided to record images of the experimental subjects.
- b) Individual frames shall be recorded on-board at intervals to be determined by the PI, but constrained by the available recording capability.
- c) Capability to telemeter some images shall be provided, when the flight path permits, at the discretion of the PI.
- d) The PI shall have limited ability to vary the imaging selection capabilities from the ground, constrained only by the system capabilities and available image recording capability.
- e) Automatic programmed imaging at specified intervals shall be the normal mode of operation.

3.2.2.2.2.3 Post Flight Data. The majority of data acquired by the RM shall be recorded on-board for post-flight downloading and analysis, including most of the video imaging and other experiment information.

3.2.2.2.2.3.1 Environmental Data. The SM shall record and store all environment measurements provided by the EM for analysis after recovery.

3.2.2.2.2.3.2 Image Data. The SM shall record and store all flight images provided by the EM for analysis after recovery.

3.2.2.3 Data Acquisition Subsystem. The Data Acquisition Subsystem shall:

- a) Receive commands from the RRV.
- b) Execute those commands at the appropriate time.
- c) Transmit experiment data to the RRV computer for transmittal at a later time or for recovery after landing.
- d) Acquire and record video images.

- e) Acquire RM status data during the mission.
- f) Control operations within the cages.

3.2.2.3.1 Command Type. Command types shall be limited to discrete and serial magnitude. No toggle types of commands are allowed.

3.2.2.3.2 Command Structure and Format. The RRS commands consist of a flag, address and data field. Six of the addresses are reserved for PM definition and use. The detailed command and structure format shall be as defined in Addendum A-RM-1 of RRS-IFS-101.

3.2.2.3.3 Data Type. Data types shall consist of analog data, discrete data, discrete commands, and video images.

3.2.2.3.4 Data Structure and Format. The same data structure shall be used for onboard storage and downlink telemetry to facilitate ground request for stored data. All data shall be uniquely identified and time tagged for unambiguous identification and reconstruction within any six-month time period by inserting tags as indicated in Table I.

3.2.2.3.5 Timing Signals. The Data Acquisition and Storage Subsystem shall receive RRV event timing signals for inclusion in the experiment data bus.

3.2.2.3.6 Experiment Data Generation. The PM shall generate experiment data and provide it to the RRV for further processing.

3.2.2.3.7 Data Transmission. The SM shall, upon command, transfer requested experiment data to the RRV for downlink to the ground control station.

Table I. Time Tag Format

COARSE TAG:	Hourly within data memory and at beginning of each transmission		
	Module	5 b	32 types
	Mission	5	32 missions
	Time	<u>14</u>	170 d, 15 min res
		24	
MEDIUM TAG:	At beginning of each data block (15 min repeat cycle)		
	Format	6 b	64 formats/types
	Time	<u>10</u> b	17 min, 1 sec res
		16	
FINE TAG:	For each individual time critical designated item within a data block		
	Time	16 b	1 sec 18 hr resolution

3.2.2.4 Power Subsystem Characteristics

- a) The RM shall operate electrical systems in a manner which will limit total power consumption (from the time of disconnect of power umbilicals before liftoff to the connection of outside power sources after touchdown) to not exceed 113 WH per orbit.
- b) The power budget shall provide for adequate margin to cover some deviations from nominal power usage.
- c) The RRV shall provide all power for use by the PM.
- d) The PM shall regulate power to 28 Vdc $\pm 10\%$.

3.2.2.4.1 Electrical Power - EM. The EM shall use regulated and converted electrical power provided by the SM.

3.2.2.4.2 Power Distribution and Control - SM. The Power Distribution and Control unit shall:

- a) Regulate all power obtained from the satellite bus to maintain acceptable ranges for the RM.
- b) Convert the satellite bus voltage to other voltages and tolerances as required by RM hardware.

- c) Provide for sufficient fault and overcurrent protection.
- d) Meet the electromagnetic compatibility requirements for the system.

3.2.2.5 Lighting Subsystem Characteristics. The lighting subsystem shall:

- a) Provide the "light" and "dark" cycles as specified for the experiment.
- b) Provide power conversion if alternating current power is required.
- c) Respond to commands, delivered via 1553 bus, from the RRV main computer.

3.2.2.5.1 Illumination

- a) The RM and ground test modules shall illuminate the inside of the animal cages in order to maintain the health and well being of the experimental animals.
- b) The same light/dark cycle shall be used to schedule illumination of all cages and the light intensity inside all cages shall be the same.
- c) All illumination on surfaces visible to the experimental animals shall be diffused.

3.2.2.5.2 Infrared. If infrared illumination is used to allow imaging or photography during the "dark" part of a light/dark cycle, the intensity and spectrum of the illumination shall be TBD.

3.2.2.5.3 Intensity

- a) During the "light" part of every light/dark cycle, the light intensity shall be within the range 40 lux \pm 35 lux (16.4 mW/cm²) in the middle of every cage.
- b) During the "dark" part of every light/dark cycle, the light intensity on any surface visible to an animal shall be less than 0.2mW/cm².

- c) Light intensities shall be measured with no animals in cages.
- d) The light intensity on any surface visible to an animal shall not vary by more than $\pm 10\%$ during a flight of up to 60 days duration.

3.2.2.5.4 Periodicity

- a) The durations of the "light" and "dark" portions of the light/dark cycle shall be separately selectable in 30 minute increments within the range of 0 minutes to 15 hours with an accuracy of ± 1 minute.
- b) The total duration of a complete light/dark cycle shall be selectable in 30 minute increments within the range of 0 minutes to 30 hours.
- c) The "start" time of the light or dark shall be selectable by command from the ground, from the RRS, or from the module controller.
- d) The module shall allow the phase of the light/dark cycle to be reset to any point by command from the ground, from the RRS, or from the module controller.

3.2.2.5.5 Spectrum

- a) During the "light" part of every light/dark cycle, the spectrum of the illumination shall be the same as the spectrum of natural sunlight.
- b) The reference shall be 1200 hours at a middle latitude on June 21.

3.2.2.6 Reentry Subsystem Characteristics

Not applicable to Rodent Module.

3.2.2.7 Thermal Subsystem Characteristics

- a) The RM and ground test modules shall control temperature inside each cage during orbital flight to remain within $\pm 2^{\circ}\text{C}$ (3.6°F) of any set point within the range of 18°C to 26°C (65° - 79°F).

- b) During the launch and recovery phases of a mission, the RM may allow the temperature inside each cage to move out of the range above, but the temperature shall not exceed 30°C for more than 0.5 hours or 35°C at any time.
- c) When experimental animals are present, the RM and ground test modules shall maintain temperature to 18°C at all times.

3.2.2.7.1 Air Circulation

- a) The RM and ground test modules shall provide continuous air flow through each animal cage.
- b) The flow speed shall remain constant during a flight within $\pm 5\%$.

3.2.2.7.1.1 Air Velocity - Maximum. The maximum air flow through each animal cage shall not exceed 240 ft/minute at any point within the cage.

3.2.2.7.1.2 Air Velocity - Minimum. The minimum air flow through each animal cage shall be sufficient to maintain the environment described in 3.2.

3.2.2.7.2 Heat Exchanger

- a) A heat exchanger shall be used to establish a heat balance in compliance with requirements of 3.2.2.7 a.b.c.
- b) The heat exchanger shall remove condensate to maintain the proper humidity levels.
- c) The heat exchanger shall contain a fusible wax to operate as a heat sink when the coolant loop is unavailable.
- d) Adequate heat sink shall be available for three hours of internal cooling.
- e) The heat exchanger weight shall not exceed 21 lbs.
- f) The heat exchanger shall interface with the RRV coolant loop.

3.2.2.8 Structures Subsystem Characteristics. The RM structure shall allow the animal cages and enclosed animals to be installed into the RM according to the pre-launch timeline and removed from the RM according to the post-recovery timeline as detailed in RRS-SS-100.

3.2.2.8.1 Structural Margin of Safety

- a) A positive margin of safety (MS) shall be maintained in designing the RRS hardware.
- b) The qualification load shall be 1.5 times maximum the expected flight load.

3.2.2.8.2 Mass Properties

- a) The CG for the PM shall be along the Z-axis no more than 7 inches from the attach point, and no more than 1 inch laterally from the PM center line.
- b) During the course of the mission, the CG shall not shift more than 2 inches toward the nose of the PM.

3.2.2.8.3 Weight. The combined weight of the PM plus consumables stored in the RRV shall not exceed 1,000 lbs.

3.2.2.8.4 EM. The EM provides accommodation for the experiment specimens on the RRV. In the case of the RM, the EM consists of 18 cages arranged in 3 decks of 6 each. Each cage occupies 60 degrees of the circular deck. The EM includes the support structure for the cages and the various installed equipment such as instrumentation harness, water distribution lines, lighting provisions, and biomedical instrumentation. The circular EM is located in the RM, on the spacecraft axis and between the recovery parachute container and the nose of the reentry shroud.

3.2.2.8.4.1 Cage System

- a) The cages shall provide for housing of the experiment specimens.
- b) The cages shall be reconfigurable for different experiments.
- c) The cages shall contain all hardware necessary to maintain animal life and other experiment data.
- d) Each cage shall provide foot holds for rat locomotion and access to food and water.

3.2.2.8.4.1.1 Group Cages

- a) Group rat cages shall be designed to house as many as six rats per cage.
- b) The group cages shall be configured to occupy the physical space allocated to six individual cages.
- c) Group cages shall be easily modifiable to allow inclusion of small compartments for mating, birthing, nursing, etc.

3.2.2.8.4.1.2 Individual Cages

- a) Each individual rat cage shall be designed to house a single 600-gm rat according to the NIH Standards of reference document (a).
- b) The height of each cage shall be 7 inches (17.78 cm) to allow a 600-gm rat to stretch out to full length.
- c) Each cage length shall be 11 inches and the width 12 inches tapering to 2 inches.
- d) Each cage shall have a minimum floor area of 70 square inches and a volume of 490 cubic inches.
- e) Each cage shall be designed to provide a uniform airflow and to prevent "dead air" spaces.
- f) Each cage shall provide foot holds for rat locomotion and access to food and water.
- g) Each cage shall be easily modifiable in order to allow animals as small as 70 gm to be housed comfortably and with security.

3.2.2.8.4.1.3 Cage Support Structure (CSS)

- a) The CSS shall provide the attachments and interfaces for a maximum of 18 cages.
- b) The CSS shall be a free-standing structure without the cages.
- c) The CSS shall accommodate the cables and tubes necessary for connection to the cages.
- d) The CSS shall allow cages to be removed and installed quickly.
- e) The CSS shall allow for removal of wastes.

3.2.2.8.4.2 Clearances. The EM shall be designed to fit within the SM volume with adequate clearance for mounting and for ease of removal/insertion from the SM.

3.2.2.8.4.3 Dimensions. The EM shall be housed in an SM with measurements not to exceed 30 inches in height and 33 inches in diameter.

3.2.2.8.4.4 Weight. The EM shall not exceed 270 lbs when fully loaded with experimental specimens and all necessary hardware.

3.2.2.8.5 SM

- a) The SM is the lower portion of the PM pressure vessel, in proximity to the EM and with the necessary connections to enable the SM to provide the specified services to the EM.
- b) The connections shall be located and configured to allow the EM to be disconnected from the SM and readily removed from the RRV.

3.2.2.8.5.1 Structural Support Subsystem. Structure of the SM shall be designed to provide the necessary support and required structural integrity as is required for the RRV in terms of loads associated with normal and

emergency operational environments, including consideration of worst case nominal operational ground contact conditions after reentry.

3.2.2.8.5.1.1 General. The SM Structural Support Subsystem shall maintain the structural integrity of the RM.

3.2.2.8.5.1.2 Load Distribution. The SM Structural Support Subsystem shall be capable of supporting all loads.

3.2.2.8.5.1.3 Mounting Adaptors. The SM Structural Support Subsystem shall:

- a) Provide mounting adaptors for the EM.
- b) Provide support for hardware contained in the SM.

3.2.2.8.5.2 Clearances. The pressure vessel shall be designed with adequate clearance for mounting and for ease of insertion/removal from the RRV.

3.2.2.8.5.3 Dimensions

- a) The exterior pressure vessel length shall not exceed 85 inches.
- b) The exterior pressure vessel shall have a lower diameter not to exceed 32 inches and an upper diameter not to exceed 35 inches.

3.2.2.8.5.4 Weight - SM. The SM shall not exceed 625 lbs when loaded with the EM.

3.2.2.9 Payload ECLSS Subsystem Characteristics

3.2.2.9.1 Atmosphere. When experimental animals are present, the RM and ground test modules shall maintain

all atmosphere parameters as described below at all times.

3.2.2.9.1.1 Composition

- a) The RM and ground test modules shall maintain the oxygen partial pressure of air which is circulated through the animal cages within the range of 18% to 22%.
- b) The RM and ground test modules shall maintain the CO₂ partial pressure less than or equal to 1.0% (7.6 mmHg max).
- c) The RM and ground test modules shall use air as required to maintain the total pressure within the range described in Vehicle Segment Specification RRS-VS-200, paragraph 3.2.2.8.

3.2.2.9.1.2 Humidity. Relative humidity within the animal cages shall be maintained within the range 40% to 70% (55 ±15%).

3.2.2.9.1.3 Quality

- a) Air entering the animal cages shall be filtered to remove particulates, contaminants, and microbes which might adversely affect the animals.
- b) Air entering the animal cages shall be treated to limit trace contaminants to less than the amounts listed in Table II. Animal trace contaminant production rates are also listed.

Table II. Trace Contaminants Limits and Rates*

Contaminant	Maximum Acceptable Contaminants (ppm)	Generate Rate (gm/man-day) **	Required Air Vent Rate (lb/man-day) **
Ammonia	25	2.5-1	1.84
Methane	1000	4.70-2	8.66-2
Acetaldehyde	10	8.30-5	1.53-2
Acetone	100	1.30-4	2.39-3
Ethyl Alcohol	17	4.00-3	4.33-1
Methyl Alcohol	13	1.40-3	1.98-1
n-Butyl Alcohol	3	1.30-3	7.98-1
Methyl Mercaptan	0.1	8.30-4	1.53
Hydrogen Sulfide	1	7.50-5	1.38-1

* NASA specification SXHS 7800, Revision H
** Estimate 18 rodents = 1/2 man

3.2.2.9.1.4 Pressure. Atmosphere pressure within the animal cages shall be maintained within the range of 14.0 psi to 14.9 psi.

3.2.2.9.1.4.1 Pressure Control Subsystem

- a) Cabin atmospheric composition shall be maintained by makeup of air leakage and metabolic oxygen consumption using two cabin pressure regulators.
- b) The air regulator shall be set at 14.4 ± 0.2 psia to maintain total cabin pressure.
- c) The oxygen regulator shall be set at 14.2 ± 0.2 psia.
- d) A pressure relief valve shall be included which will provide for (1) atmospheric purging in the event of pressure build-up (2) periodic removal of trace contaminants, via manual command.
- e) The oxygen flow control valve shall have a flow-limiting orifice to set the design metabolic consumption at 0.81 ppd.

3.2.2.9.1.5 Atmospheric Revitalization Loop. The Atmospheric Revitalization Loop shall consist of the following components:

- a) Debris Trap.
 - 1) The debris trap shall have a screen to remove solid matter.
 - 2) The debris trap shall have an automatic bypass pressure relief to maintain flow in the event of blockage of the screen.
- b) Atmospheric Revitalization Loop Fans. The air flow shall be maintained by small vaneaxial fans (redundant) which supply $10 \text{ ft}^3/\text{minute}$ of air flow at 3.0 inches of water.
- c) Check Valves. Check valves shall be used to prevent backflow of air in the Atmospheric Revitalization Loop fans.
- d) CO_2 Absorber.
 - 1) CO_2 removal shall be accomplished with a packed bed absorber containing LiOH.

- 2) The LiOH shall be contained in multiple module canisters to facilitate reconfigurations for other missions.
- 3) The amount of LiOH in the absorber shall not exceed 77 lbs.
- e) Temperature Control Bypass Valve. A temperature control bypass valve shall be included in the heat exchanger ducting to provide the ability to trim the cooling capacity.

3.2.2.9.2 Drinking Water

- a) Potable water shall be readily accessible to each rat on demand.
- b) The water system shall prevent back contamination from the cages to the water supply.
- c) The water system shall provide at least two water dispensers in each cage.
- d) The water system shall allow either dispenser to be disconnected from the water supply by a command.
- e) The amount of water provided for each rat shall be calculated from the amount of food provided according to the ratio of 1 ml of water for each 1 gm of food.
- f) The amount of water provided for each rat shall be at least 30 ml per day.
- g) The amount of water available shall include allowances for wastage, animal consumption patterns, spillage, and unusable amounts.
- h) Drinking water shall meet the requirements outlined in NIH Publication 85-23.
- i) As required by specific experiments and experimental animals, drinking water shall contain iodine in concentration no greater than 4 ppm or chlorine in concentration no greater than TBD ppm.

3.2.2.9.3 Waste Management Subsystem

- a) The Waste Management Subsystem shall collect all wastes generated by the experimental animals.

- b) The Waste Management Subsystem shall prevent collected waste from reentering the animal cages.
- c) If chemicals are used in the Waste Management Subsystem, they shall be prevented from contact with the animals during all phases of a mission.
- d) Waste includes but is not limited to urine, feces, dander, loose fur, glandular secretions, and food particles.

3.2.2.9.3.1 ACVL Fans

- a) The ACVL fans shall operate intermittently to provide sufficient airflow to dislodge waste.
- b) The ACVL fans shall operate with a pressure drop of 0.5 inches of water to generate air flow of 150 to 300 ft³/minute.
- c) The ACVL fans shall operate with a maximum of 12 W power with a 10% maximum duty cycle.

3.2.2.9.3.2 Waste Filters

- a) The waste filters shall include a particulate screen for removing solid matter.
- b) The waste filters shall include an activated carbon/chemical filter for controlling trace contaminants.
- c) The waste filters shall include additional trace contaminant removal provided by an overboard vent of 0.2 ppd.
- d) The waste filters shall include removal of other trace contaminants.

3.2.2.9.4 Nutrient Storage and Distribution. The nutrient storage and distribution subsystem shall:

- a) Provide food and water to the animals.
- b) Provide measures of the amount of nutrients consumed within each cage.
- c) Control the access of the specimens to nutrients.
- d) Provide for waste of nutrients.

3.2.2.9.4.1 Food Design

- a) Food shall be readily accessible to each rat on demand and shall be protected so it is not contaminated by rat waste products.
- b) The quantity of food provided for each rat shall depend on the energy value of the food.
- c) The quantity of food available in the flight and ground test modules shall include allowances for wastage, animal consumption patterns, and unusable amounts.
- d) The diet shall consist of nutritionally adequate food with an energy value of at least 4 kcal per gram.
- e) The food shall be soft enough to allow the rats to readily gnaw.
- f) The food shall be hard enough to prevent excessive growth of their teeth, unless an alternate substance for gnawing is provided.

3.2.2.9.5 Rats

- a) The flight and ground test modules shall be designed to support 18 rats for 60 days.
- b) Cages shall be designed to house all rats individually or in groups.

3.2.2.9.6 Fluid Storage. Fluid storage shall be provided by the RRV through interfaces with the PM. In the PM:

- a) Shutoff valves shall be provided for the air/oxygen/water storage tanks.
- b) Fill valves shall be provided for the air/oxygen/water storage tanks.
- c) Pressure regulators shall be provided for the air/oxygen/water storage tanks.
- d) A water tank air pressure regulator shall be provided to pressurize the expulsion bladder on the water storage tank.

- 3.2.3 Reliability. As specified in Specification RRS-SS-100, Section 3.2.3, and subsequent paragraphs.
- 3.2.4 Maintainability. As specified in Specification RRS-SS-100, Section 3.2.4 and subsequent paragraphs.
- 3.2.5 Environmental Conditions. As specified in Specification RRS-SS-100, Section 3.2.5 and subsequent paragraphs.
- 3.2.6 Transportability. As specified in RRS-SS-100, paragraph 3.2.6 and subsequent subparagraphs.
- 3.2.7 Reusability. As specified in RRS-SS-100, paragraph 3.2.7 and subsequent subparagraphs.

3.3 DESIGN AND CONSTRUCTION

As specified in RRS-SS-100, Section 3.3 and subsequent paragraphs, with the following additions.

- 3.3.1 Cage Coatings. Cage coatings shall be of materials which are compatible with the animals and will not harm the animals if digested.
- 3.3.2 Cage Materials. Cage parts shall be constructed of materials which will not be damaged by chewing, will not harm experimental animals during contact, and will not produce volatiles which will harm the animals.
- 3.3.3 Cleanliness
 - 3.3.3.1 Microbiological Contamination. Before introduction of experimental animals, the interior of the RM and ground test modules and the animal cages shall have less than 50 colony-forming units of microorganisms per 100 cm² of surface area.

3.3.3.2 Module Cleanliness

- a) Before introduction of experimental animals, the RM and ground test modules shall be free of particulate and nonparticulate contamination such as scale, rust, dust, dirt, grease, oil, water, feces, urine, blood, saliva, food, and other foreign materials when examined by the normal unaided human eye.
- b) The modules and animal cages shall be easy to clean and disinfected before and between missions, and methods of cleaning shall not leave residues which are harmful to the experiments.
- c) The design of the RM shall allow restoration to pre-flight condition of cleanliness and operability by use of readily available, economical cleaning methods and materials.
- d) The cleaning materials shall not deposit dangerous or unacceptable residues on the SM.
- e) Cleaning materials and any residue resulting from the use of cleaning materials shall not be toxic to nor in any way affect the experimental subjects nor the installed equipment.

3.3.4 Mechanical Design Criteria

3.3.4.1 Integration and Test Compatibility. The RM shall be designed and fabricated using modular system elements which provide separability for independent testing and certification as well as ease of integration and system qualification/certification.

3.3.4.2 Physical (Maintenance and Test) Access

- a) The RM shall provide for ready physical access to system elements by use of modular design.
- b) Physical interfaces shall be designed with use of quick-disconnects and verifiable re-connects to enhance accessibility during maintenance and troubleshooting.

3.3.5 Off-Loading

- a) In case of a pad abort or post-touchdown, consumables shall be off-loaded, including nontoxic materials such as water and rodent food. The RM will not contain any hazardous materials, but shall be designed to preclude contamination of the RM interior or the experimental subjects by the toxic propellants during off-loading.
- b) If practical, such off-loading shall be conducted when the RM and/or the EM have been removed from the RRV.

3.3.6 Purging

- a) Purging of RM systems shall be accomplished as a part of post-flight refurbishment.
- b) Materials used for purging containers (such as the debris trap for fecal matter from rodent cages) shall not cause any deleterious effects upon the installed equipment nor deposit any residue not approved for exposure to the experiment subjects.

3.3.7 Handling and Lifting. The RM shall be equipped with hoisting and handling features such as hooks and hard points which will allow ready handling, hoisting, emplacement, and tie-down for transport and for installation and removal from the RRV.

3.3.8 Computer Resources. As specified in RRS-SS-100, paragraph 3.3.8 and subsequent subparagraphs.

3.3.9 External Power

- a) The RM shall be equipped with integral receptacles which will receive standard electrical power connectors used on general purpose carts at the launch sites.
- b) The RM shall accept standard launch site auxiliary power, which meets the general voltage and amperage needs of the RM, without degradation to the RM systems.

3.3.10 Alignment Reference. The RM shall display, in prominent locations, alignment reference marks with adequate precision to allow RM alignment for determination of RM contribution to the RRV kinematic characteristics (moments of inertia, etc.).

3.3.11 Interface Connector Verification. The RM design and construction shall provide for verification of secure mating of all connectors necessary for installation of the RM in the RRV or GCEM for flight or ground operations, respectively. Verification may be by direct observation and physical verification or by other means, if the connectors are not directly observable.

3.4 DOCUMENTATION

As specified in RRS-SS-100, paragraph 3.4.

3.5 LOGISTICS

3.5.1 Maintenance

3.5.1.1 Maintenance Definitions. As specified in RRS-SS-100, paragraph 3.5.1.

3.5.1.2 Maintenance Objectives. The RM design shall conform to the RRS maintenance goal of readily removable and replaceable modular system elements.

3.5.2 Supply

- a) The provision of consumables and spare/replacement parts for the RM shall be planned based upon evaluation of previous experience and history of related and similar reusable space systems such as the Discoverer Program and the Space Transportation System.

- b) Stock levels shall be established based upon two flights per year for ten years.

3.5.3 Facilities and Facility Equipment

- a) To the maximum practical extent, the RM shall use existing NASA facilities for all phases of flight and flight support operations.
- b) The RRV shall accept and integrate the EM and SM at the experimenter's facility, with only the final experiment subjects being installed at the launch locations.
- c) The RM shall be integrated into the RRV, checked out, and certified as flight-ready at the launch facility.

3.5.4 Recovery Force. The RM will require special handling at the recovery site to permit removal of the RM as soon after touchdown as reasonably possible. Exact procedures shall be defined after it is decided whether to remove the PM from the RRV at the touchdown location, or to move the entire RRV to the location of the post-flight laboratory facility and remove the EM there. In either case, there will be a requirement for a suitably trained recovery force. Specific personnel requirements are as specified in RRS-SS-100, paragraph 3.5.4.

3.6 **PERSONNEL AND TRAINING**

As specified in Specification RRS-SS-100, Section 3.6 and subsequent paragraphs, with the following additions.

3.6.1 Personnel. The RM flight support personnel will be part of the RRV team and defined by overall RRS needs. The RM experimenters will provide personnel to install, check out, and certify flight readiness of the RM and the installed EM and SM.

3.6.1.1 Launch. During and prior to launch, the RM will require only support console monitoring and stand-by contingency capabilities. The latter will only be needed in the case of an on-pad abort. Nominal personnel requirements will be for console monitoring of PM status.

3.6.1.2 Operations

- a) To the maximum extent practicable, the RM experiment, like the RRS orbit operations, shall operate without active human intervention, in accordance with pre-programmed and validated electronic direction stored on-board.
- b) Changes shall be initiated when the telemetry indicates a deviation from pre-programmed operation, an unfavorable trend, an emergency or threatened emergency, or when the PI determines that a change is required for scientific reasons.
- c) Mission consoles shall be manned only when necessary; the flight instrumentation shall be designed to limit the number of monitoring personnel and the time they must spend in direct supervision of the mission.

3.6.1.3 Recovery. The recovery team shall be trained to recover the RM and to access the EM as rapidly as possible.

3.7 PRECEDENCE

As specified in RRS-SS-100, paragraph 3.7.

4. QUALITY ASSURANCE PROVISIONS

As specified in RRS-SS-100, Section 4.0.

5. PREPARATIONS FOR DELIVERY

As specified in RRS-SS-100, Section 5.

6. NOTES

As specified in RRS-SS-100, Section 6.

APPENDIX I

**GROUND/PECULIAR SUPPORT EQUIPMENT (GSE/PSE)
FOR THE
REUSABLE REENTRY SATELLITE (RRS)
RODENT MODULE (RM)**

10.1 SCOPE

This appendix establishes the performance, design, development, and test requirements for the ground and peculiar support equipment (GSE/PSE) required to support factory, pre-launch and post-launch operations associated with the Rodent Module version of the RRS Payload Module.

10.2 APPLICABLE DOCUMENTS

As specified in RRS-SS-100, paragraph 2.0.

10.3 REQUIREMENTS

- 10.3.1 System Definition. The RM GSE/PSE is that support equipment needed in addition to the Vehicle Emulator (VE) provided as CFE by the Reusable Reentry Vehicle (RRV) contractor for RRV/PM interface qualification and pre-launch base integrated testing.
- 10.3.2 Characteristics. The GSE/PSE shall be designed in a manner which does not need additional GSE/PSE for normal operations. Detailed characteristics are TBD.
- 10.3.3 Design and Construction. The GSE/PSE shall be designed to best commercial practice consistent with RRS-SS-100 safety requirements.
- 10.3.4 Documentation. - TBD
- 10.3.5 Logistics. - TBD
- 10.3.6 Personnel and Training. The GSE/PSE shall be operable by the basic RRV/RM support contingent and the training integrated with the basic PM/RM training specified in RRS-RM-200.

10.3.8 Precedence. RRS-SS-100, RRS-RM-200, and RRS-IFS-101 takes precedence over any requirements in this appendix in the event of conflict.

10.4 **QUALITY ASSURANCE PROVISIONS - TBD**

10.5 **PREPARATION FOR DELIVERY - TBD**

10.6 **NOTES - TBD**

APPENDIX II

**GROUND TEST MODULE
FOR THE
REUSABLE REENTRY SATELLITE (RRS)
RODENT MODULE (RM)**

20.1 SCOPE

This appendix establishes the performance, design, development, and test requirements for the Rodent Module version of the RRS Ground Test Module (GTM).

20.2 APPLICABLE DOCUMENTS

As specified in RRS-SS-100, paragraph 2.0.

20.3 REQUIREMENTS

- 20.3.1 System Definition. The RRS GTM is a non-flight RM which may be used in conjunction with the Vehicle Emulator (VE) to conduct ground control experimentation in support of the overall payload objectives. The combined GTM/VE, also known as the Ground Control Experiment Module (GCEM), is described in detail in RRS-SS-100, Appendix I, Ground Control Experiment Module.
- 20.3.2 Characteristics. The GTM shall be form/fit/function identical to a flight RM with the following exceptions:
- a) The GTM does not have to withstand flight loads.
 - b) The SM shell does not have to be a pressure vessel and may have windows for the purpose of observing experimental specimens.
- 20.3.3 Design and Construction. The GTM shall be designed to best commercial practice consistent with RRS-SS-100 safety requirements.
- 20.3.4 Documentation. - TBD
- 20.3.5 Logistics. - TBD

20.3.6 Personnel and Training. The GTM shall be operable by the basic RRV/RM support contingent and the training integrated with the basic PM/RM training specified in RRS-RM-200.

20.3.8 Precedence. RRS-IFS-101 takes precedence over any requirements in this appendix in the event of conflict.

20.4 QUALITY ASSURANCE PROVISIONS - TBD

20.5 PREPARATION FOR DELIVERY - TBD

